tension. In flexion, the radius is pushed forward, and projects somewhat beyond the end of the ulna, impinging upon the radio-carpal bone (scapholunar), and pushing the pinion around the centre of motion of the wrist-joint so that it is more or less flexed. In extension, the reverse motion takes place, from the pulling back of the radius. The proposition is carefully demonstrated, illustrated with three figures, and likewise shown to be susceptible of ocular proof by direct experiment. Several interesting corollaries are also drawn. Some such mechanism is shown to be an anatomical necessity, from the structure of the wrist-joint, to provide for the extremes of adduction and abduction that take place in the wrist, without straining the joint. Another obvious purpose subserved is equalization of muscular power, by relegating a part of the work, that the hand muscles would otherwise have to perform, to the larger flexors and extensor of the upper arm; and an actual saving of a certain amount of muscular effort, this being replaced by automatic movements of the bones themselves. Having seen no account of this mechanism, the author is inclined to think it may be unnoticed.* It is at any rate a new explanation of the design of the peculiar shape and position of the radial articulating surface of a bird's humerus, far more important than that hitherto assigned, viz.: its causing simply the well-known *obliquity* of flexion of the forearm.

On the Geological History of the Gulf of Mexico.—By Prof. Eug. W. Hilgard.

This paper, accompanied by a geological map, treats of the formations that have gradually filled up the ancient Mississippi embayment, existing after the upheaval of the Palæozoic rocks; whose vertex, a few miles above the junction of the Ohio and Mississippi, is marked by the small Tertiary area in Illinois. The author hopes that a close comparison of these deposits with those of the Far West, with which they were and partly still are connected, may lead to the more accurate parallelization of the latter with the marine deposits of more distant regions. Most of the subject

* It is indeed not mentioned in the works of Cuvier, Meckel, Tiedemann, Wagner, and other distinguished authors; but Dr. Bergmann, of Gottingen (*Archiv. fur Anat.*, 1839, 296), speaks of essentially the same thing, although the results of the mechanism are not so fully shown.

matter here referred to is embraced in the author's publications for ten years past.*

The most ancient shoreline of this embayment is formed chiefly by the Carboniferous rocks. The oldest formation cropping out within these limits is the Cretaceous, which east of the Mississippi traverses the states of Alabama, Mississippi and Tennessee, reaching a short distance into Kentucky, along the Carboniferous ridge which borders the Tennessee river. The dip is 20-25° at right angles to the trend of the formation, which in its southerly portions is very distinctly subdivided into three chief groups, whose equivalents seem to be readily traceable in the Northwest. But towards the northern, narrow end of the outcrop, the distinctions become less defined, and the character more or less lignitic.

West of the Mississippi, in Arkansas, the outcrop does not extend so far north by some one hundred and fifty miles. It there corresponds to the middle group, the lowest not having thus far been recognized; while the upper one appears to be represented in the series of Cretaceous outliers existing in Louisiana, forming, apparently, a Cretaceous "backbone" to that state, whose southernmost point is, probably, the rock-salt mass of Petite Anse. The sulphur and gypsum of Calcasieu, likewise, seem to belong to this epoch, but their precise mode of formation can at present only be guessed at.

During the Tertiary period, the shoreline receded from its extreme head in southern Illinois, to near the latitude of Baton Rouge, running nearly parallel to the present one. This seems to show comparative shallowness; and this point is confirmed by the predominantly lignitic and lignito-gypseous character of the deposits, especially in the upper part of the embayment, where small outliers only of a marine character exist. The lignitic feature repeats itself throughout the predominantly marine deposits of the later times; less so in Alabama than in Mississippi, while in Louisiana it largely predominates, owing probably to the presence of the Cretaceous "backbone." In general each marine group has its lignitic equivalents; and since lignitic outliers connect across Texas, with the great basins of the interior, a close study of their flora (and possibly fauna) may, it is hoped, enable

* Rep. on the Geology and Agriculture of Mississippi, 1860. Am. J. Sci. May 1866; Ibid. July 1866; Ibid. Nov. 1866; Ibid. Jan. 1867; Ibid. Jan. 1869; Ibid. Nov. 1869. Rep. U. S. Engin. Dept. 1870; Am. J. Sci. March, April and May, 1871.

us to determine the equivalents in time of the marine Tertiary groups.

The Vicksburg series of rocks, ends the marine Tertiary of the Southwest; the transitions between its fauna and the older Eocene are so cogent as to render any great separation in time or space inadmissible. The Vicksburg deposits are rather of a deep-sea character, less lignitiferous than the stage next below. But the Miocene and Pleiocene deposits, observed on the Atlantic coast, are unrepresented on the waters of the Gulf, save by beds equally devoid of a marine or fresh water fauna, and with but very few and poorly preserved remains of plants. A single fragment of a turtle has been found in a clay stratum filled with calcareous concretions, possibly the remains of a fauna destroyed by maceration. These "Grand Gulf" beds lack all analogy outside of the Gulf basin, unless it be in the interior, perhaps, in the Bad Lands of Nebraska, whose analogues have now been found so much farther south than heretofore supposed, that a connection may have been possible; the lithological resemblance is very great—at all events, since the Grand Gulf rocks alone represent the period between the Eocene and Drift, they include the equivalents in time of the White river beds as well as others.

It seems impossible to account for the character, thickness and position of these beds, without assuming that after the close of the Eocene period, the Gulf was either cut off from the Atlantic, or communication was so slight as to cause the continental waters to freshen the brine so much as to destroy the marine fauna, without rendering it fit for fresh water life. An upheaval of the northern border of the Caribbean would even now readily produce such an isolation, were it not for the deep channels excavated by the Gulf stream, in the straits of Yucatan and Florida. Since on the farther Antilles Miocene and Pliocene beds have been found, it is evident that this state of things was confined to the Gulf basin. The geology of Cuba and Yucatan is too little known to determine how far they were concerned in the same.

The Grand Gulf as well as the older rocks are almost everywhere overlaid by the "Orange Sand" or stratified Drift; while on the Palæozoic territory it is more or less localized in conformity with the larger valleys. On the area under consideration, it forms a huge delta-shaped mass, consisting mainly of ferruginous and variegated sand and subordinate clay beds, and traversed by

several pebble streams, the largest of which occupies the axis of the embayment. Its beds disappear beneath those of the Port Hudson era almost concurrently with the Grand Gulf rocks.

The phenomena offered by these deposits, as heretofore shown, require the assumption that prior to its deposition the Gulf coast suffered an elevation of at least four hundred and fifty feet above its present level, accompanied by a much greater one at the head of the waters. Then there occurred a slow depression to about twice that amount, and finally, during the Terrace epoch, a reëlevation to at least the extent of four hundred and fifty feet. The northern derivation of the pebbles, their size, and the extensive plowing-up of older beds, prove a southward flow of waters, of considerable violence.

These events were of no local character; they are intimately connected with, and the complement of, the Drift phenomena of the Northwest. It is time that the facts of the case were generally understood and taken into account by American geologists, and that the Ohio should cease to be proclaimed the southern limit of the Drift. Its southern representative has mostly, heretofore, been erroneously associated with contiguous formations of every age.

An understanding should be come to as to what is meant by the word "Drift." In New England it means chiefly moraine material; in the West, what is presumed to be iceberg drift; in the South, materials clearly stratified and transported almost exclusively by water. All are properly included in the *Drift Epoch*, defined as embracing the time between the termination of the Tertiary, and the beginning of the Champlain era of quiet deposition and slow depression.

The next succeeding formation is the Port Hudson series of swamp, lagoon, fluviatile, estuarian and littoral deposits, formed during the slow depression of the continent. It underlies not only a wide littoral belt, now partially covered by the waters of the Gulf, but also the entire alluvial area of the lower Mississippi, Red, and other larger rivers, then constituting extensive fresh water estuaries; their general valleys having, evidently, already been impressed upon the surface during the later Drift period, though not always coincident with their present ones. Late observations made in the Yazoo and Tensas bottoms confirm the statement, made by Gen. Humphreys in 1860, that the Mississippi

and its bayous have mostly cut their channels into a clay formation foreign to the alluvium, from which some of the best soils of these bottoms are also directly derived; the alluvium being, on the whole, of little thickness.

These clays form the lower division of the Port Hudson beds. The upper consists chiefly of yellow and whitish silts which at some points form a terrace along the edge of the bottom; while on the hilltops of the adjoining uplands lies the calcareous, silty loam (Loess), of the Bluff formation, differing from its equivalents farther north by the total absence of stratification, and the exclusive prevalence of terrestrial fossils. How this state of things was brought about, it is not easy to imagine, unless perhaps the tidal flow was instrumental therein.

Above the Loess we find usually a stratum of loam or brick clay, which near the larger rivers is sometimes 15–20 feet in thickness. It is devoid of stratified structure as well as of fossils, and forms the sub-soil of most of the uplands of the Gulf States.

The Terrace epoch has not left any marks in the way of beach lines or terraces distinctly referable to that era. As regards the modern epoch, the Mississippi Delta presents the anomaly of progressing, not by simple alluvion, but through the singular agency of the Mudlumps, discussed in a paper lately published.*

Col. CHARLES WHITTLESEY said he was gratified to find so many facts conspiring to sustain a theory of his own and a favorite theory of fifteen years standing, that the Quaternary of the Lower Mississippi is cotemporary with the later epochs of the Northern Drift.

He thought it was now demonstrated that the bluff or Loess beds of the upper and lower Mississippi are identical. At the north there are instances of coarse transported materials overlying and underlying the Loess. The blue, variegated, and red clays of the upper beds are closely allied in age with the Loess and are probably cotemporary with it and the Champlain clays.

This Loess or bluff stratum extends from above the Falls of the Mississippi to below Natchez, and forms a connecting link between the gulf deposits and those of the north. He suggested that there was a reasonable explanation of their common origin when we consider that the Glacial period was one of great length, and also considering the state of things as it was gradually drawing to a close. Such a vast accumulation of ice and nevè, exceeding two thousand feet in thickness, required a long period for its dissolution, and in dissolving produced a vast fresh water sea, covering a country nearly flat, but having a drainage to the south.

* Am. Jour. Sci., March, April and May, 1871.

The currents must have been broad, powerful and deep, and operating always in one direction, were capable of transporting materials of considerable coarseness a thousand miles. Hence mud, loam and clay would be carried indefinitely. Agates and cornelians, whose home is in trap rocks above the Falls of St. Anthony, are found scattered along the valley to the mouth of the Ohio. If they travel at the rate of only a rod in a year, three hundred and twenty years would find them advanced a mile gulfward, and ten thousand years more than thirty miles. A current of four miles an hour, extending from the western base of the Cumberland Mountains in Tennessee to the foot of the Ozark Mountains in Missouri would fill up a space equal to a large state in a century.

It appeared to the speaker that here is a simple and sufficient explanation for the translation, in the later parts of the ice period, of so much northern gravel sand, loam, and even of small boulders to the vicinity of the gulf and into it.

Below the states north of the Ohio, pieces of the native copper of Lake Superior are not found in the Quaternary gravel. The water forces were not equal to the transportation of so heavy a material, nor of magnetic iron boulders and gravel. Both the copper and the heavy iron ores of Lake Superior are common in the Drift of the Lake country, but they required the propelling force of moving ice to send them along. Beyond the ice or glacier field, deep and persistent currents of water were able to take up and move forward the lighter materials to places many hundred miles distant, provided the element of time is sufficiently great.

In this way we may synchronize the whole field of the Quaternary of the United States east of the Rocky Mountains and perhaps that of the Pacific slope.

Dr. C. A. WHITE was much interested in the able paper of Professor Hilgard, especially as hitherto so very little has been brought out concerning the phenomena of the Post-tertiary period in that latitude. While conceding the facts observed, and the conclusions arrived at by him there, I must, nevertheless, maintain that we of the Upper Mississippi valley have not been mistaken in ours. In Iowa we have a very different set of Post-tertiary phenomena, and yet I believe true explanations of both may, and ultimately will be, completely harmonized by careful study of the broad region intervening between those that he and I have respectively studied.

The Post-tertiary deposits of Iowa consist of the true, unaltered, unstratified Drift, so well known in that region and elsewhere, through the more or less distinctly stratified gravelly or sandy drift observable in the valley sides above the reach of floods, to the alluvium of their flood-plains. Besides this, we have, in Western Iowa, that very interesting deposit resting upon the drift which Professor Swallow has called the Bluff deposit. This deposit, doubtless, had essentially the same origin as that to which Professor Hilgard has given the same name in Louisiana, namely, in the muddy waters of the Missouri river, although the deposit, doubtless, never had direct continuity, but was interrupted by broad

barrier elevations of the surface, through which the river cut its valley during the Terrace epoch, as I have defined it for our region. I have been able to recognize there only two epochs of the Post-tertiary period, namely, the Drift and Terrace epochs; but, at the same time, I fully concede all that is claimed for the existence of phenomena upon the sea-coasts upon which the Champlain epoch is based. The Drift epoch, with us, is understood to have ended with the disappearance of the ice, and the Terrace epoch to have continued from that time to the present. The terraces I understand to be parts of flood-plains abandoned from time to time as the valleys were deepened by the action of the waters of their own streams, for I can see no evidence that they were produced, even in part, by any elevations or depressions of that part of the continent. At the close of the Drift epoch, we may assume that Iowa had a nearly level surface, averaging, as it does now, about eight hundred feet above the level of the sea, the highest point being about seventeen hundred feet above, and the lowest, the southeast corner, four hundred and forty-four feet above that level. The valleys have all been eroded out of this general level by their own waters, and this is believed to be quite sufficient to account for the existence and character of the terraces. These terraces are found in the Bluff deposit as well as in the altered Drift, showing that the Bluff deposit must have originated early in the Terrace epoch. The deposit was formed in a large lake-like expansion of the Missouri river, caused by a broad depression that was left in the surface of the Drift at the close of the Drift epoch, and became filled with the silt of the muddy stream that flowed into and from it, which, finally deepening its valley below, had only to sweep out a part of the silt, which became the Bluff deposit, leaving the terraces, as it did, in the Drift.

Professor A. WINCHELL felt prepared to corroborate fully Dr. Hilgard's views in reference to the absolute continuity of the upper portion of the Drift deposits in the Northern and Southern States. He had studied these deposits from the Gulf of Mexico to Lake Superior, and in the Southern States, especially along the Black Warrior and Alabama rivers, and had expressed the conviction to Prof. Tuomey as long ago as 1852, and had published it in the "Cleaveland Proceedings of the Association" in 1853, that he found no grounds for assigning the semistratified deposits of the Southern States to a different age from the so-called "altered Drift," of the North. They all seem to be composed of similar materials (modified certainly by local circumstances), and to have been transported from the higher lands of the continent at the same time, and by agencies of a similar character.

Dr. G. LITTLE had studied this subject for a quarter of a century. When a small boy it was his custom with his playmates to "fight rocks;" one boy would take one of these pebbles from the immense gravel beds on which the city of Tuscaloosa, Alabama, is located and attempt to break another chosen by his companion. Although ignorant of mineralogy, he soon discovered that those pebbles which were clear and glass-like (Quartz) proved the hardest to break — they were sometimes half as

large as a boy's head, more frequently of the size of the fist — very smooth on the surface, and often egg-shaped. It was a matter of curiosity to him to inquire whence these rocks came and how they became rounded and polished.

Some years later he was so fortunate as to become a pupil of Prof. M. Tuomey in the University of Alabama. That excellent geologist, at that time, twenty years ago, attributed the gravel beds, on which Tuscaloosa and several of the capitals of the Southern States (Milledgeville, Ga., Columbia, S. C., Richmond, Va.), are situated, to the same agency whose action was described in the north as producing the Drift phenomena.

At a still later period, as State Geologist of Mississippi, Dr. T. traced these beds from Tuscaloosa to Columbus, Miss., to Eastport, Tenn., and along the edge of the Carboniferous to the Ohio. The same beds he saw along the northern lakes. From these high northern latitudes came then the materials of what is called Drift in the Southern States by Dr. Hilgard, in his paper. Quartz, from its hardness, furnishes the largest pebbles and the sand grains. The coloring matter of the Red Clay which forms so much of the surface of the Gulf States comes from the iron beds of Lake Superior.

Professor PERRY, having recently made a somewhat detailed examination of the principal geological formations in Mississippi, was happy to be able to say that he had not become acquainted with a fact which militates against the main views advanced by Professor Hilgard.

While all geologists are familiar with the three series of Cretaceous formations in Alabama and Mississippi, it may be proper for me to mention that Cretaceous deposits of peculiar interest have been recently discovered by Professor Kerr, at Snow Hill in North Carolina. Under his guidance, I had the pleasure of visiting the locality, last spring, shortly after their discovery. They appear to be of about the same age as the Ripley group of Mississippi, and are equally rich in organic remains; while they contain according to Professor Conrad a large number of genera and species new to science. The discovery is destined, no doubt, to add a new chapter to the history of the American Cretaceous.

After a rather careful investigation of the Tertiary beds of Mississippi, I have found no occasion to take exception to the main conclusions reached by Dr. Hilgard and published in his Geological Report of the State. Of the uplift to which he refers in his report and in the paper read, running about west-north-west and east-south-east, which was first mentioned by Professor Tuomey, I found abundant evidence in both Alabama and Mississippi.

In regard to the existence of Mississippi Drift, the subject of more especial interest at this time, I may say that I find no room for doubt. The prominent features of this formation, as it occurs in Mississippi and Alabama, I had opportunity to study between the years 1847 and 1850. I then became acquainted with the phenomena, while their explanation has been only gradually reached by the continued studies of subsequent years.

During the past season, I desired, as occasion was afforded, to verify or disprove, by an actual list of facts, the previous views in regard to the question of southern Drift. Taking the circuit of the Atlantic and Gulf States, and thence proceeding up the valley of the Mississippi, I discovered at almost every step what to me is unmistakable evidence of glacial agency, all the way around from Virginia to Illinois. I have studied the Drift of New England for years, I think I know it in its main features —typical Drift and modified Drift in most of its varying forms. Now, in all the states referred to, I found that which I could not distinguish, after making the necessary allowance for local differences, from New England Drift.

As to the direction in which the agency worked, I find variations which were, no doubt, eagerly determined by the face of the country; variations which indicate that the deposits assumed the form which they now have, in what was the closing part of the Glacial period, in the Southern States. The beds seem to go out in rays from the Appalachian mountains, from the Blue Ridge towards the Atlantic, in the Gulf States for the most part southward, and in the Basin of the Mississippi towards the southwest.

Reference having been made to a supposed elevation and depression of the country, I would suggest that the facts relied on as evidences are perhaps susceptible of another and more simple explanation. Remembering that, in the formation of the immense ice-mass that spread over much of the continent, there must have been a considerable depression of the ocean; also that the thawing of the extended mass of ice at the close of the Glacial period must have produced immense floods of water, we have what was no doubt equivalent to a moderate elevation and depression, and a cause sufficient to account for all the manifestations of glacial agency with which we meet.

Prof. E. C. ANDREWS said that in the prosecution of the geological survey of the State of Ohio by Prof. Orton, he found in the Drift deposit, buried beneath eighty feet of drift material, a peat-bed and a buried forest containing wood, plants and mosses in their original position, and so perfectly preserved that a number of living species have been identified. That is in the very midst of our drift material in Montgomery county, in Southern Ohio. The formation there is coarse gravel and drift material, and I think not stratified.

Prof. RICHARD OWEN mentioned that it has not been adverted to, that on the north shore of Lake Superior the rocks which have furnished the Drift that we find in the whole Mississippi Valley are in sight. Then, as we go south, these detached boulders are found at first in large, then in smaller and constantly smaller fragments, ranging in size from those of many hundred tons weight down to a ton or two in this region, and finally, south of the Ohio river, weighing only perhaps from one hundred to one hundred and fifty pounds and those giving place in turn to deposits in the form of sand, ending finally in beds of sand on the shores of the Gulf of Mexico. Now, without stopping to advert to the great theory as

to the elevations which brought up the Apallachians and the Rocky Mountain ranges and sent this Drift centrifugally through, I will merely say that there are portions of Indiana in which, when we go through that gravel, we find rocks that have been polished off and then grooved in a north and south direction, which proves that from the rocks away north of Lake Superior, the northern and southern Drift are continuous, becoming smaller as you go south, borne there by the oceanic currents, and afterward, as the land rose, dropped in the form of fresh water deposits, accounting for the large boulders in the north, the beds of gravel in the south, the beds of peat and all the varied phenomena that have been observed in connection with the subject of the Drift.

Professor HILGARD remarked, in reply, that, in the South at least, the Drift epoch was easily defined as reaching from the termination of the latest Tertiary period to the beginning of the deposition of the Port Hudson beds (equivalent to those of Dana's Champlain period); when all deposits that could properly be designated as "drifted," ceased to be formed outside of river channels. Where the Champlain depression had not caused submergence, it might be marked by subaërial deposits, such as had been observed in an apparently corresponding position, by Dr. Edmund Andrews, of Chicago. He thought the southern stratified Drift corresponded to the "modified Drift" of the West, though on a very large scale; but it would not do to call it by that name, which could apply only to a small portion in the axis of the embayment. Elsewhere it was modified Carboniferous, Cretaceous and Tertiary; the materials of these formations having been simply plowed up and redeposited farther south by the Drift waters. No name could be altogether distinctive and characteristic, yet in this case the stratification was so to a very great degree, and he thought the name of "Stratified Drift" might properly be made to embrace the southern Drift as well as the "modified" Drift of the Western States.

At the present time, the winter ice of the Mississippi frequently runs past Vicksburg. How much more must the ice-floes and bergs of the Glacial period have reached at least that latitude, down to which we find, even though rarely, boulders of northern derivation, too ponderous and too little worn to have been transported by water alone. Quartzite pebbles of a couple of pounds weight occur even at the island of Petite Anse, together with other smaller ones of northern rocks; and a profusion of those derived from the Grand Gulf rocks, whose nearest outcrop lies about sixty miles due north.

In reply to a question as to what he now thought of the age of the rock-salt deposit of Petite Anse, Prof. HILGARD stated that he thought it of the Cretaceous age. It was older than the Drift, by which it was overlaid; and its great thickness and purity, as well as the absence of analogy, militated against its connection with any of the Tertiary stages. On the other hand, the Cretaceous of northern Louisiana was preëminently salt-

bearing, and Petite Anse lay right in the line of a series of Cretaceous outliers indicating an axis of upheaval, Cretaceous limestone occurring within sixty miles of Petite Anse. Moreover, the limestone and gypsum of Calcasieu, between which lies the sulphur bed, are distinctly represented in the Cretaceous of northern Louisiana, while totally foreign to any of the Tertiary stages; and although the great gypsum bed has not been reached at Petite Anse, it lies in the proper line of dip, and seems to form a complement to be looked for, of the great rocksalt bed. These probabilities fall short of proof, it is true, but weigh heavily when we consider the simplicity of the geological structure of the Mississippi embayment; where departures from the general rule are so unlikely as to throw the burden of proof upon whosoever maintains their existence.

ON THE CARPAL AND TARSAL BONES OF BIRDS.—BY PROF. EDWARD S. MORSE.

THE author stated that he had followed with great interest the work of Huxley, Cope, and others in tracing out the ornithic characters in the Dinosauria. While following these relations he had noticed a marked difference in the characters of the carpus and tarsus of the two classes. It seemed strange that a group of bones so persistent in the reptiles as well as in the mammalia should be so obscure or wanting in birds. Owen objects to the term tarso-metatarse as he believes the existence of a tarsus has not been demonstrated. W. S. Parker, in 1861, on the osteology of Balœniceps, questions if the lower articular portion of the tibia is not the homologue of the mammalian astragalus and not an epiphysis. Gegenbaur has now shown that in one stage of the young bird there is a proximal tarsal ossicle, and a distal tarsal ossicle, the first one anchylosing with the tibia, the distal one likewise anchylosing with the metatarse. Thus, the term tarso-metatarse is quite proper. While this was a great step toward a proper understanding of these parts, Mr. Morse believed that a nearer relation would be found in the discovery of another proximal tarsal bone. In those reptiles he had examined, whatever the number of tarsal bones, there were always in the proximal series one corresponding to the tibia, and another corresponding to the fibula. He had found this feature in birds. In studying the embryos of the eave swallow, bank swallow, king bird, sand piper, black bird, cow black bird, blue bird, chirping sparrow, yellow warbler, and Wilson's thrush, he had found three distinct tarsal bones, two in the proximal series answering to the tibia and fibula, and one in the